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TITLE- Real-Time Control of an Emplaced ALSEP: Review of the Requirements and Estimate of the Duty Factor on the Proposed Computer

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ABSTRACT

Current planning includes real-time data processing and control of an emplaced Apollo Lunar Surface Experiments Package (ALSEP) by use of an IBM 360/50 computer located in the Mission Control Center-Houston (MCC-H). The decision to use the IBM 360/50 presupposes that a portion of its capability will be available for non-ALSEP work. ALSEP requirements are reviewed to determine which functions will have the greater call on this computer for real-time support and the time-dependent constraints imposed by these functions.

It is concluded that a dedicated computer will not be required throughout the lifetime of ALSEP. Rather, the requirement is one for computer availability, on a priority basis, during certain reasonably predictable periods. The more critical of these periods will occur during the initial deployment and checkout of each ALSEP and during the occurrence of events which cause rapid changes in the lunar environment such as sunsets, sunrises, and solar flares.

The percentage of ALSEP data which will actually be processed in real-time will be heavily influenced by factors, such as conflicts with programs of equal or higher priority, whose net effect will be determined only at the time they occur. The authors believe that the ALSEP will require real-time computer support 100% of the time for the first 10 days or so of operations, this factor gradually decreasing to 50% by the twenty-fifth day, to 25% by the forty-fifth day and leveling off at a 10% factor until the next ALSEP is emplaced. ALSEP data handling in other than real-time should not be a serious problem insofar as computer loading and scheduling are concerned.

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TECHNICAL MEMORANDUM

1.0 INTRODUCTION

The first of three planned Apollo Lunar Surface Experiments Packages (ALSEP) containing four or five basic experimnets is scheduled to be emplaced on the moon during the second Apollo landing. It has been decided that real-time control of the emplaced ALSEP and real-time processing and display of its telemetry data will be performed by an IBM 360/50 computer located in the Mission Control Center at Houston (MCC-H). A recent sizing estimate indicates that the IBM 360/50 computer will be able to support two ALSEPs simultaneously.(1)

The decision to use the IBM 360/50 presupposes that a portion of its capability will be available for non-ALSEP work. In this memorandum we evaluate the validity of the ALSEP real-time requirements, consider the impact of these requirements on the utilization of the IBM 360/50 and estimate the fraction of the IBM 360/50 capability that will be available for other activities.* The handling of ALSEP data in non-real-time including strip-out of scientific data for the Principal Investigators (P.I.) will not be accomplished by the real-time computer system and hence will not be considered here.

GSFC experience in the use of relatively low cost Pulse Code Modulation Data Handling Equipment (PCM-DHE) is briefly discussed in Appendix A to this memorandum. The applicability of this equipment to ALSEP in order to provide better data coverage and to allow more latitude in the scheduling of the IBM 360/50 should be examined.

2.0 FUNCTION AND PURPOSE OF ALSEP

ALSEP is a man-emplaced, lunar surface, scientific station. It consists of a power source and a Central Station to which a variety of experiments from a number of scientific disciplines can be attached. The Central Station provides power distribution, data collection and transmission, and command receiving. Data collected from the experiments are processed into a telemetry format by the Central Station.

*While we limit the discussion to ALSEP Array A only in this paper, the conclusions apply to Arrays B and C as well. The conclusions also apply to the Early Apollo Science Experiment Package (EASEP), which will be emplaced on the moon during the first lunar landing.

Frame rate in the nominal mode is $\frac{53}{32}$ frames per second. Each frame contains 64 data words of 10 bits each or 640 bits per frame. The basic bit rate is 1060 bps.

In this section we briefly describe each ALSEP experiment, noting particularly its data and command capability and its priority. We will find that the lower priority, lower reliability experiments have more complex formats.

2.1 Engineering Experiment

ALSEP can be considered as the prototype of the multi-disciplinary long-lived geophysical observatories which will monitor the lunar surface and its sub- and near-surface environment for decades. As such, early emplaced ALSEPs will be studied to assess the adequacy of the present engineering design to ensure the success of immediate follow-on ALSEP flights and to identify modifications needed to extend lifetimes and to optimize operations. Current planning suggests that advanced ALSEPs will not differ markedly from those now built and that they, as well as present ALSEPs, will be flown on 9-12 months centers.

2.2 Passive Seismic Experiment (PSE)

This experiment, by far the most important scientifically, provides 80% of the ALSEP data rate and is assigned to every flight. Indeed, one can regard ALSEP as a seismic observatory with a number of shorter lived auxiliary experiments attached. The PSE consists of:

a. A three-axis long period (15 second) seismometer measuring vector ground displacements with a resolution of 1 nanometer at 1 Hz, a dynamic range of 80 db at a rate of four vector samples per frame.

b. A leveling servo output which yields the tidal amplitude to a resolution of about 8 μgal at a rate of 1/2 vector samples per frame.

c. A short period vertical seismometer with a resolution of 1 nanometer at 1 Hz, a dynamic range of up to 1 μm and a data rate of 29 samples per frame.

d. A sensor thermometer, important for thermal control and spring constant determination, which measures temperature in the range 107°F to 143°F with a resolution of about 0.1°F.

e. A commandable kick coil for calibration.

The experiment in operation will quickly determine the lunar seismic background and will thenceforth be operated in a dynamic range (gain setting) just below the microseismic, or noise level.

2.3 Lunar Surface Magnetometer (LSM)

This experiment uses three fluxgate magnetic sensors to measure the vector magnetic field (either ambient or solar wind induced). The most sensitive range is ± 100 nanotesla (gamma) with an accuracy of 0.5%. Two other ranges are commandable (± 200 and ± 400 nanotesla) but will probably be used infrequently if at all. The magnetometer data handling subsystem uses 7 words of the ALSEP telemetry frame, 6 of which represent 2 samples of the magnetic field vector, while the 7th is subcommutated among 30 engineering measurements and status words. A total of 8 commands are available, only one of which (flip/cal) will be repeatedly exercised during a nominal mission.

After turn-on and calibration the LSM is commanded into a site survey mode consisting of 14 automatically sequenced steps designed to detect any local magnetic anomalies which might be caused by the presence of a nearby meteorite. This is performed only once; the rest of the experiment is conducted in a quiescent observatory mode monitoring magnetic transients caused by changes in the solar wind flux. Periodic calibrations are automatically sequenced every 12 hours with commands available to inhibit or initiate the sequence (probably during sunrise and sunset periods for the first few months).

The LSM is nominally an observatory type instrument. Due to lunar orbital magnetic surveys which have already been conducted (Anchored IMP) few surprises in the data are expected; however, any surprises that do occur will be of fundamental importance.

2.4 Solar Wind Spectrometer (SWS)

The SWS is a broad spectrum, directional particle detector using 7 modified Faraday cups to monitor solar wind influx from various segments of space. The high voltage applied to the cups is automatically sequenced in order to scan a spectrum of 10.5 to 1,376 ev in 7 steps (electrons) and 75 to 9,600 ev in 14 steps (protons). The data channels are multiplexed into a single stream consisting of 186 words per SWS data cycle, (i.e., 46.5 ALSEP frames). The only command available is used to switch the low voltage to a high mode.

2.5 Suprathermal Ion Detector Experiment (SIDE)

The SIDE is an ion mass spectrometer capable of resolving ionic masses up to 120 amu with energies from 0.2 to

48.6 ev. In addition, a high energy detector will count particles from 10 ev to 3,500 ev independently of the mass. In order to compensate for possible electric fields a ground plane is deployed under the instrument. The ground plane voltage (with respect to the instrument) can be stepped from 0 to ± 27.6 volts. The three variable voltages (velocity filter, energy filter, ground plane voltages) are automatically sequenced through their ranges. An entire data cycle requires over 6,000 ALSEP frames or approximately one hour to complete. However, elimination of ground plane voltage stepping (after a few days) will reduce this to about 3 min/cycle. Five ALSEP command lines are used by SIDE to encode and execute 15 commands. Of these 15 commands, 12 are classifiable as contingency commands (i.e., resetting frame counters, switching high voltage) and approximately 3 commands may be exercised on the order of once a month.

2.6 Cold Cathode Gauge Experiment (CCGE)

This experiment is packaged with, and shares the electronics of, the SIDE. Its output data stream is multiplexed with the SIDE data. The one command used by the CCGE (high voltage on/off) is tabulated as one of the SIDE commands. The CCGE measures the density of neutral atoms (i.e., lunar atmospheric pressure). Although it is classed as a relatively low priority experiment, it is important to fly it on the early missions because of possible contamination of the tenuous lunar atmosphere ($< 10^{-10}$ torr) with rocket exhaust.

3.0 REAL-TIME CONTROL OF ALSEP

Data can be retrieved from ALSEP in real time -- within seconds of their transmission from the Central Station - via telemetry links, the remote sites, and the communication lines of the Manned Space Flight Network. These data are used as bases for observing and controlling ALSEP health and experiment operations.

The degree and amount of real-time control capability needed to support any space vehicle is a function of what can be done to command its operation and overcome malfunctions. In this section we discuss the control capability of ALSEP, its reliability and failure modes, its intended operation and, in light of these factors, assess the real-time flight control requirements as currently stated by MSC.*

*References (2) (3) (5) and (8) contain detailed statements of current requirements for ALSEP real-time control.

3.1 Control Capability of ALSEP

The ALSEP command decoder is capable of accepting 66 different commands.[5] We estimate that, of the 66 commands available, 28 will be used occasionally, 35 rarely and 3 one-time only. Note that only 28 commands are allotted to all 4 experiments so that the ALSEP control capability is fairly modest.

Seven one-time commands are automatically generated by the command decoder 96 hours after plug-in of the Radioisotope Thermoelectric Generator (RTG). These (see Table II) backup the prime action by the MCC-H in the event of receiver failure. They blow the SWS (two commands) and SIDE dust covers (two commands), break the CCGE seal and uncage the PSE. One one-time command turns off the receiver at the end of two years, resets the receiver circuit breaker and insures that power is restored to the fourth (lowest priority) experiment in the event a "ripple off" of experiment power has occurred due to overload. These are essentially "backup" commands since, with a normally operating ALSEP, they would be redundant and unneeded. A summary of ALSEP backup command-systems is given in Table III.

In normal operation, most ALSEP housekeeping data are redundant and a complete printout of all parameters will not be needed. Listings will be required after commands are exercised; during the remaining periods the computer could periodically limit-check selected parameters.

3.2 Summary of Activities Requiring Real-Time Control

Table I summarizes stated requirements for ALSEP real-time data support. This support may be grouped, chronologically, in five phases for purpose of analysis:

a. Deployment/activation on lunar surface.

b. Initial experiment checkout and calibration.

c. First forty-five days of activity.

d. Forty-sixth day to end of first year.

e. End of first year to turn-off of ALSEP.

3.2.1 Deployment/Activation on Lunar Surface

Requirement:

Present planning envisions ALSEP deployment by the two-man astronaut team during the second EVA period.[2] During the deployment/activation phase, two activities will require real-time monitoring or real-time control from the ALSEP MCC-H: 1) activation and turn-on of the station, and 2) alignment and checking of the antenna. Following ALSEP deployment, turn-on of the station and transmitter is by ground command upon astronaut request. The flight crew will stand by the Central Station until the MCC -H has checked out the system.[3] If ALSEP does not respond to ground command, contingency action is taken by the astronaut through the operation of three switches. Switch No. 1 starts the Power Conditioning Unit (PCU) converter oscillator. This switch is activated in any event as a backup to the ground control. Switch No. 2 performs three functions: 1) it turns on transmitter B; 2) it turns on Data Processor Y; and 3) it resets the command receiver. Switch No. 3 is a gang switch which applies power sequentially to the four experiments--the Passive Seismic Experiment (PSE), the Lunar Surface Magnetometer Experiment (LSM), the Solar Wind Spectrometer (SWS), and the Suprathermal Ion Detector Experiment/Cold Cathode Gauge Experiment (SIDE/CCGE) in that order,at approximately 0.1 second intervals. Final switch positions are reported to the MCC -H by the astronaut. The MCC -H acknowledges this report and, in turn, reports ALSEP status to the astronaut.

The astronaut also can perform a realignment of the antenna. Normal procedure calls for alignment to the center of the earth's libration for the coming year. Pointing data are obtained from an aiming table before departing the LM. These data are checked and verified by the MCC -H flight controllers. Following alignment the astronaut requests turn-on by remote commands. Signal strength and signal characteristics are checked by the MCC-H and, in the event further optimization is desired, the astronaut can manually adjust the antenna alignment using offsets supplied by the MCC-H until the desired performance is achieved.

All of the deployment/activation operations will be conducted in concert with the MCC -H and will be monitored and commanded in real time. Following turn-on of ALSEP, it is planned to have the crew perform a geological traverse during their return to the LM. ALSEP is monitored by the MCC -H during this traverse and also during the time the LM is departing the lunar surface in order to detect any disturbance of the lunar environment caused by astronaut or LM action. Initial checkout, and experiment calibration and turn-on, may begin at this point or alternatively await return of the LM to Earth.

<u>Assessment</u>:

Barring inflight emergencies necessitating full devotion to crew safety by the MCC -H, the requirement for real-time commanding and data monitoring during this deployment/activation phase may be considered to be "hard" since it is difficult to conceive how these activities could be successfully accomplished otherwise.

3.2.2 Initial Experiment Checkout and Calibration

Requirement:

This phase follows the emplacement of ALSEP on the lunar surface. It begins with the initial checkout and activation of the experiments and ends when all systems have been exercised and base line data have been obtained. The sequence, summarized, is as follows:

(1) Seismometer (PSE)

Initial Checkout (spot check of telemetry transmission of engineering and scientific data).

Leveling

Thermal Check

Collect Base line Data

(2) Magnetometer (LSM)

Initial Checkout

Sensitivity Range Adjustment (400 nanotesla → 200 nanotesla → 100 nanotesla)

Flip/Calibration (PSE scientific data also checked simultaneously for evidence of cross-talk and motion)

Collect Base line Data

(3) Solar Wind Spectrometer (SWS)

Initial Checkout (PSE scientific data also checked for motion during removal of dust cover)

Thermal Check

Collect Base line Data

(4) Flip/Calibration of Magnetometer -- (Repeat of Flip/Calibration Sequence)

(5) Suprathermal Ion Detector (SIDE)

Initial Checkout

Thermal Check

Calibration

Collect Base line Data

(6) Flip/Calibration of Magnetometer -- (Repeat of Flip/Calibration Sequence)

(7) Initial Checkout of Cold Cathode Gauge (CCGE) -- (PSE scientific data checked for evidence of seal break)

(8) Flip/Calibration of Magnetometer -- (Repeat of Flip/Calibration Sequence). At this point, sensor temperatures are monitored continuously for one hour or until stabilization is confirmed before commencing the next function which is site survey

(9) Site Survey with Magnetometer

(PSE scientific data checked for evidence of mechanical operation)

(10) Dust Detector Checked

Assessment:

The initial checkout sequence, summarized above, takes approximately 20 hours to complete. It begins at any time following completion of the deployment/activation phase. Once begun, it should be completed without interruption since, if anomalies occur, time constrained decisions will be made concerning fixes and whether or when to proceed to the next step. Thus, one may categorize it as a "real time but anytime" sequence.

3.2.3 First Forty-Five Days

Requirement:

The requirement stated for this time period is for continuous real-time monitoring of data in order to develop confidence in the ALSEP system and to make necessary adjustments. The forty-five day period spans the first two lunar day/night transitions which are the most critical insofar as status is concerned.

Assessment:

The need for continuous real-time data transmission and processing, especially during the early portion of this period, will be influenced by:

(1) The lunar environment, which could range from dynamic to quiescent,

(2) The thermal effects of the sun on ALSEP,

(3) The actual health of ALSEP,

(4) The effects on ALSEP circuitry and thermal balance of fluctuations in power usage, including underload, in the event experiment malfunctions should occur.

Additionally, it will be desirable to detect the major scientific events (e.g., a moonquake) as soon as possible. Once experience has been gained, both with the ALSEP system and with the lunar environment, continuous real-time data monitoring can be markedly reduced if not discontinued entirely.

The requirement for continuous monitoring during the forty-five day period after deployment would prevent the IBM 360/50 from being used for any other activity. However, we believe that computer time could be made available for other purposes, at least during the latter part of the period. For the first ten days or so, until the first lunar sunset, continuous monitoring to ensure temperature stabilization and to satisfy scientific interest can be justified. Following the first ten days, there will be interest in monitoring continuously the thermal control system during the first few sunsets and sunrises. However, once temperatures stabilize and confidence has been achieved that limits will not be exceeded, or not approached rapidly, there will be little need for continuous monitoring. Also, it is not at all certain that the lunar geophysical environment will be of a sufficiently dynamic nature to require continuous real-time transmittal of scientific data to the MCC-H. Very likely the requirement will reduce to one which states a need for a continuing availability rather than use of a real-time capability. Much of the time should be available for work of higher priority. Since all data will be recorded on tape at the remote sites and will be available for normal processing, the need for real-time processing will have to be weighed against its cost as well as against the other uses to which the facilities can be put.

3.2.4 Forty-Sixth Day to End of First Year

Requirement:

In recognition of the expected increase in confidence in ALSEP operation, requirements are drastically reduced following the 45th day after deployment. The requirements for real-time data from the forty-sixth day until the end of the first year are, as stated by MSC, summarized below:

(1) Twice a day for at least two continuous hours per day - Monitor telemetry and compare against limits.

Check SIDE engineering data and compare against limits; check SWS temperatures and calibration voltages. Spot check passive seismic scientific data. If tidal data indicate instrument has shifted off level, proceed with leveling sequence.

(2) Once a day - check high energy and low energy SIDE data alternately for one hour each.

(3) Once a week - check dust detector.

(4) Every 14.75 days - monitor and control thermal balance if necessary during 48 to 60 hours of the lunar sunrise and sunset period.

(5) Special - special call-ups as necessary to monitor events of interest such as unusual solar activity and aftershocks of detected moonquakes.

Assessment:

These requirements will change as experience is gained with the system. Some real-time checks may eventually not be required at all (e.g., spot check passive seismic experiment, weekly dust detector check) because of the potentially non-varying nature of the lunar environment, while others may require monitoring more often than currently estimated. Experience with the Orbiting Geophysical Observatory (OGO)* and other similar geophysical payloads suggests that the need for monitoring and commanding critical events diminishes with time and thus, considerable flexibility in when things need to be done will be allowed.(4)

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*See Appendix A

A certain amount of real-time support will be desirable during this phase. Actually, it would be beneficial to perform all of the stated required checks in a real-time mode. Conceivably, however, ALSEP could be satisfactorily and safely operated during this phase completely non-real time with all data being received and stored at the sites and called up and processed as time, resources, and interest permit. The strongest call on real-time support will come during terminator crossings which occur at intervals of 14.75 days although even here, experience will probably relax or eliminate the currently stated need for 48 to 60 hours of "continuous real-time" data. These, then, fall in the category of "wait-and-see" requirements. In general, they should not place an exorbitantly heavy duty cycle on MCC-H facilities.

3.2.5 End of First Year to Turn-Off

Requirement:

Current plans call for the operation of ALSEP for a minimum of one year. At the end of the second year (± 30 days) the Central Station timer causes the transmitter to be turned off. Following cessation of active operation of ALSEP and prior to automatic turn-off, the RF signal will be checked once a day. In the event that automatic turn-off by the timer does not occur, a command can be sent to perform this function.

Assessment:

This requirement places an inconsequential load on the real-time computer control system and can be ignored insofar as any systems loading analysis is concerned.

3.3 The Impact of Reliability on Real-Time Control

A major factor in determining the amount of real-time monitoring necessary for ALSEP is the effect of time delays in recognizing a failure and applying corrective action. In this section we discuss the types of failures that might occur during a mission, and the impact of not detecting these failures immediately.

3.3.1 Contingencies

Figure 1 is a graph of the current ALSEP reliability predictions for the Flight 1 model as a function of time. It is currently estimated that the ALSEP system array for Flight 1 has a probability of 0.35 of performing a completely successful operation of all experiments for a one year period[6] and a probability of 0.87 that the PSE will have one year successful operation. From Figure 1, we see that all experiments have a very high probability of at least one month's operation, but that the reliability of the low priority experiments rapidly degrades with time.

Thus, it is reasonable to expect that contingency operations will be needed. Presumably they could be of the diagnostic/quick fix type and result in a progressively degraded mode of operation. The experiments, or portions of them, may be expected to give out one at a time until finally the Central Station dies. Expected contingencies are not yet well documented so below we simply list some failures ALSEP has had in thermal vacuum test.

a. PSE: Caging mechanism failure; spurious signals cause execution of leveling command or gain change commands; marginal thermal control.

b. LSM: Digital filter may oscillate; sensor flipping may have difficulties.

c. SWS: High voltage arcing; dust covers fail to open completely; fail to restart when the temperature is low.

d. SIDE: High voltage arcing, dust cover may fail to open.

e. Central Station: Paint may peel off, altering thermal balance.

f. General: ALSEP uses many flat-packs on which a quality alert has been issued.

3.3.2 Time Constants and Data Loss

The ALSEP design ground rule that single-point failure modes be avoided was fairly well enforced so we may conclude that ALSEP contains no known, serious, single-point failure modes. ALSEP has a totally passive thermal control design and has no active elements such as pointing mechanisms or louvers. Critical commands such as dust cover removal, LSM calibration, etc., are backed up by timer-generated commands, so that in the event of total receiver failure most ALSEP data would still be available, albeit frozen in the operational mode established before flight. The real-time control requirement for 2 hours/day routine monitoring implies that nothing dramatic or irrevocable should happen to a nominal ALSEP in a 22 hour period and that a lame ALSEP will not destroy itself. This seems eminently reasonable and we certainly have no data, predictions or suspicions that anything to the contrary will occur. Since the change in the lunar environment is cyclic with a long period, the particle experiments would not be materially affected by some data loss and in any case would likely pick up equivalent data during an ensuing period. The LSM also looks for random magnetic disturbances but these are presumed to be rare. The PSE seeks random events which are both short in duration and rare (occur at a currently predicted constant rate of about 25 events per year) so that "data loss" here means a lower probability of event detection. The significance of this loss, if any, is difficult to judge at this time, but it is believed that little or no loss of data of significance will occur due to occasional periods of ALSEP system down-time.

4.0 SUMMARY AND CONCLUSIONS

4.1 Summary

ALSEP, being emplaced by hand on the lunar surface, requires no tracking, ephemeris updating, or vehicle orientation/stabilization; hence, many of the more time-critical functions normally associated with geophysical satellites and space probes are lacking. As a consequence, the stringent need for real-time data processing and vehicle control is reduced significantly. On the other hand, the lunar environment, with its cyclical extremes of temperature and the, as yet, largely unknown magnitude and temporal variation of its geophysical phenomena, poses uncertainties concerning the degree of real-time control that will be necessary. This is particularly the case with regard to the adjustment of thresholds and sensitivity levels of the experiments. In general, however, it is believed that, following initial calibration, such adjustments will occur infrequently. The ultimate criterion for a successful mission is that scientific data be obtained for as long as possible. It is assumed that real-time monitoring and control will be available and will be continued until this is achieved.

Valid estimates cannot yet be made of all the contingency needs that will develop. However, the limited number of commands available suggests a limited number of "fix" options and this is the important point insofar as the objectives of this paper are concerned. Further, since ALSEP is a science observatory, there will be a tendency to avoid tinkering with it once an optimum operating mode has been achieved. This will reduce further the number of real-time contingency actions that will be taken.

4.2 Conclusion

Compared with other satellite or space probe vehicles, ALSEP is a less complicated geophysical observatory in terms of the amount of control required. It will, therefore, require less real-time monitoring than other, more "conventional", spacecraft. Thus, it is concluded that the ALSEP real-time requirement is for computer availability during certain reasonably predictable periods rather than for computer dedication throughout the life of ALSEP. The more critical of these periods will be the initial deployment/checkout/activation of ALSEP and during the occurrence of events causing rapid changes in the lunar environment such as sunsets, sunrises and solar activity.

The IBM 360/50 currently planned for ALSEP control will be more than adequate. This computer need not be dedicated to ALSEP but can be shared with other programs. It is quite possible that the ALSEP requirement will be drastically reduced once the lunar environment has been probed; thus, it is possible that a significant portion of the IBM 360/50 capability could be devoted to other needs. The authors believe that ALSEP will require computer support 100% of the time for only the first 10 days or so of operations, this factor gradually decreasing to 50% at the twentieth day, to 25% at the forty-fifth day and leveling off at a 10% factor until the next ALSEP is emplaced.* ALSEP data handling in other than real time should not be a serious problem insofar as computer loading and scheduling are concerned.

A backup computer for ALSEP is not justified. Since, however, there will be occasions when data processing and display will be desirable during periods of IBM 360/50 outage a tie-in with the existing IBM 360/75 system in the MCC-H would be advantageous.

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*The EASEP package now scheduled for the first lunar landing will yield preliminary data on the geophysical activity of the moon and on the operation of the Central Station. This information will allow a more precise estimate to be made of the real-time computer requirements.

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TABLE I

ALSEP REAL-TIME

DATA REQUIREMENTS

ITEM	Contin- ually	Once Per Week	Twice Per Day	Once Per Day	Once Per Hour	As Re- quired
FROM INITIAL CHECKOUT THROUGH 45TH DAY						
Monitor telemetry & compare against limits	X					
Check magnetometer sensor temperatures					X	
Monitor power status (during Flip/Calibrate)						X
Report status to Experiment Activities Officer				X		
Check PSE scientific data	X					
Check SIDE engineering data	X					
Check HE & LE SIDE data (alt. for 1 hour each)	X					
Check SWS temperatures & calibration voltages	X					
Check Dust Detector		X				
FROM 46TH DAY TO END OF SECOND YEAR*						
Monitor telemetry & compare against limits		X				
Check SIDE engineering data & compare against limits		X				
Check HE & LE SIDE data alternately for one hour period			X			

*First year activities may be extended for second year if desired.

TABLE I

ALSEP REAL-TIME

DATA REQUIREMENTS

(CONTINUED)

ITEM	Contin-ually	Once Per Week	Twice Per Day	Once Per Day	Once Per Hour	As Re-quired
FROM 46TH DAY TO END OF SECOND YEAR (con't)						
Check SWS temperatures & calibration voltages			X			
Check PSE scientific data			X			
Check Dust Detector		X				
Report status to Experiment Activities Officer				X		
LAST 30 DAYS OF ALSEP						
Check for presence of RF signal				X		
SPECIAL						
Sunrise/Sunsets/Eclipses---Monitor TM temperatures - 24 hours with last 12-15 hours most critical						

TABLE II

AUTOMATIC ONE-TIME AND CYCLIC COMMANDS

The command decoder automatically generates seven one-time commands after a 96-hour delay. The one-time delayed command functions and time of execution are:

COMMAND NO.	FUNCTION	WHEN EXECUTED
75	Blow CPLEE dust cover	
69	Set CCIG seal break	96 hrs. + 2 mins.
59	Uncage PSE	
72	Execute CCIG seal break	96 hrs. + 3 mins.
52	Blow SWS dust cover	96 hrs. + 4 mins.
71	Set SIDE blow dust cover	
72	Execute SIDE blow dust cover	96 hrs. + 5 mins.

These one-time commands are followed by two functions which are cycled automatically for the life of ALSEP at 12 hour intervals. These are:

COMMAND NO.	FUNCTION	WHEN EXECUTED
89	Magnetometer flip/calibrate sequence	108 hrs. + 1 min. and then every 12 hrs.
42	Activate Power Distribution Unit to restore power to lowest experiment.	108 hrs. + 7 mins. and then every 12 hours.

TABLE III

SUMMARY OF ALSEP BACKUP COMMAND SYSTEMS

PRIME	BACKUP	BACKUP ACTION
MCC-H	Astronaut	Astronaut turns on transmitter, data processor and experiments by activating 3 switches on central station.
MCC-H	Timer	Timer activates a series of commands starting 96 hours after the coupling of the RTG to the Central Station. Initiates removal of dust covers from the SWS and SIDE and uncages the PSE.
Normal Mode	Timer	Generates a signal every 12 hrs. to reset the circuit breaker in the power line to the receiver.
MCC-H	Timer	At 108 hrs and 1 min. Initiates flip/calibrate sequence. At 108 hrs. and 07 mins. Insures power distribution relay of the fourth (lowest priority) experiment is in the operational power ON position. Repeats both events at 12 hr. intervals for life of ALSEP.

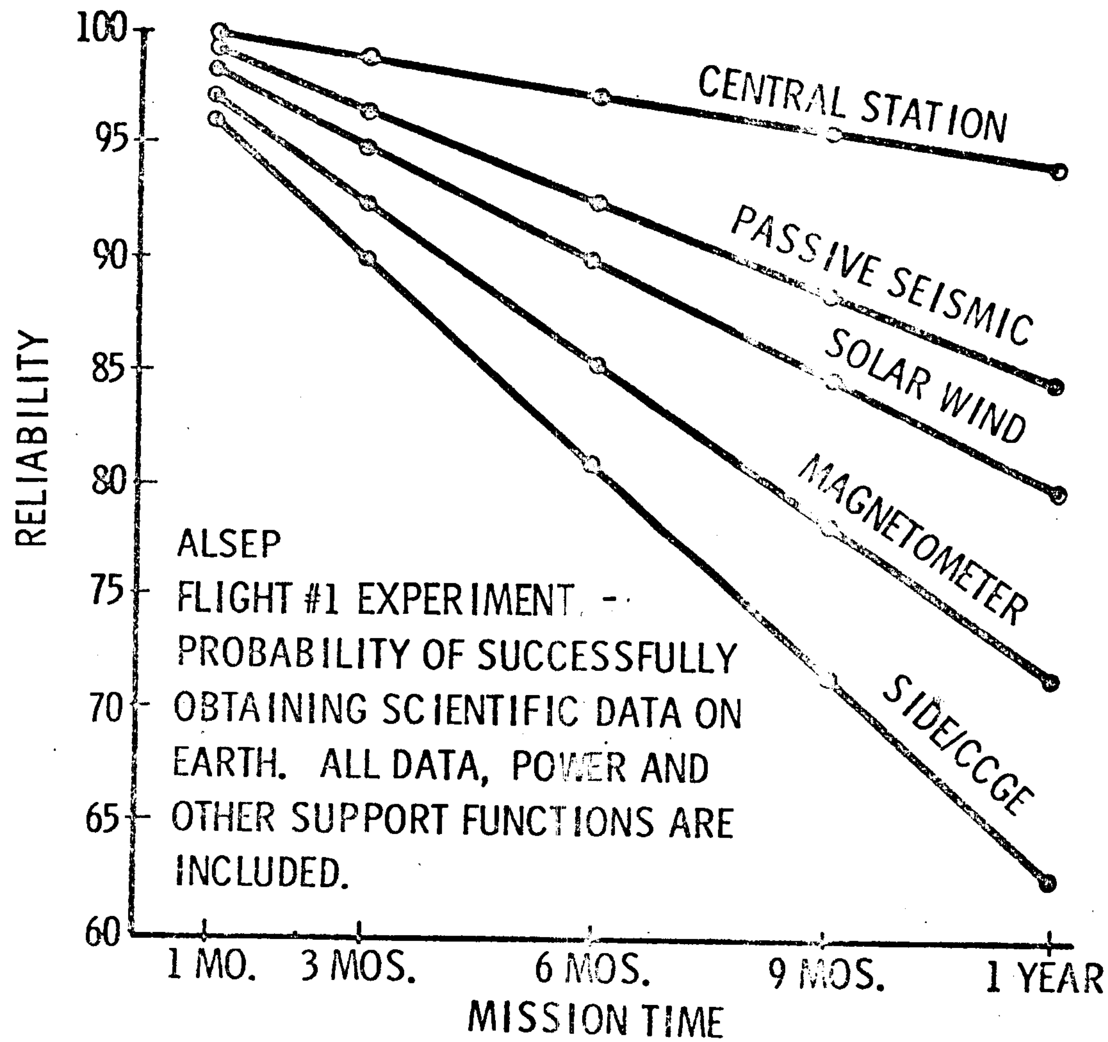

FIGURE I - ALSEP RELIABILITY PREDICTIONS FOR FLIGHT I MODEL (FROM REF. 6)

8.0 APPENDIX A

GSFC Experience with the Orbiting Geophysical Observatory (OGO) Program

In an attempt to estimate the amount of real time support a particular program or individual flight will actually use, it is helpful to refer to the flight experience of a previous program.

In some respects the OGO and ALSEP programs are similar. Both are remote, automatic, geophysical stations located in space, and both accommodate a variety of experiments which require health checking, data readout and commanding for calibration. Principal differences are:

a. Power supply--Ni/Cd batteries charged by solar cells for OGO; radioisotope thermoelectric generator (RTG) for ALSEP.

b. Type and number of experiments--20 or more, measuring cislunar environment for OGO; four or five, measuring lunar surface, subsurface and near surface environment for ALSEP.

c. Method of emplacement: Unmanned and automatic for OGO; man transported, erected and checked out for ALSEP.

d. Vehicle attitude and tracking requirements--considerable for OGO; none for ALSEP.

Considering interest in scientific data one can expect that the Principal Investigator (P.I.) interest level and the real-time data processing, computer and display requirements should bear similarities. As expected, the P.I. interest in real time OGO data diminished rapidly with time as the data points became repetitive following the first few orbits. Typically, geophysical experiments yield a maximum of new information within the first few hours or days of operation. The following weeks, months and years then tend to confirm and refine the original data. Health checks, tweaking of gains and data readouts continue indefinitely during the lifetime of the equipment but are conducted in a more routine, more easily scheduled fashion. Also, predictably, the experience level of personnel required to continue the operation decreases with time--the scientist and the senior flight controller giving way to the student and the technician. The need for real-time data receipt, processing and display is reduced accordingly.

To a degree, the total resources required for ALSEP can be identified and compared with an on-going program such as OGO. Certainly, ALSEP is a less complicated and demanding vehicle than OGO. For example, the typical OGO can respond to 256 commands while ALSEP 1 and 2 will respond to only 66. The SDS 930 computer has proven to be adequate for the OGO mission and study indicates that something less than this would be adequate for ALSEP.

The effective use by the OGO program of Pulse Code Modulation Data Handling Equipment (PCM-DHE) both as a backup to the SDS 930 computer and also as a prime means of producing analog data on strip charts is of interest. Backup is thus afforded in the event of failure of the computers and this, together with an ability to command at the remote sites, has provided an adequate redundancy in the ground system. These relatively low-cost* features could have application to the ALSEP program and should be seriously considered for possible inclusion in the ALSEP support system. One PCM-DHE unit could drive about 20 strip charts so that, for example, 10 strip charts of PSE and other experiment data and 10 for ALSEP health status could result in essentially 100% coverage during periods when the IBM 360/50 was unavailable. Although continuous coverage, (and the implied need for a second, backup computer) cannot be rigorously justified, the risk of missing in real time a scientifically significant event of great importance (such as a moonquake) will exist whenever the computer is unavailable for whatever reason. Continuous coverage by means of the PCM-DHE would eliminate this risk as well as provide more latitude in the scheduling of the IBM 360/50 for other purposes.

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*The cost of one PCM-DHE ≈ $100-120K.